Towards a Gold-Standard for Combined TMS and EEG Data Pre-Processing: A critical examination of the effectiveness and reliability of a two tiered independent components analysis approach

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Background

- Combined TMS and EEG hold the potential to expand our understanding of cognitive processes.
- However, analysis of the EEG is hindered by significant artefacts caused by the TMS pulse.
- Although artefact limiting hardware exists they are not widely available, and rely upon removing a time window of data.
- One alternative approach is ICA which has been demonstrated as an effective offline solution to the problem (Korhonen et al, 2010/11; Rogasch et al, 2014; Mäki et al, 2011) although no attempt has been made to distribute a standard method for its use in this context.

Aim

- Assess the efficacy of a standardised protocol, by demonstrating the test-retest reliability of ICA for the removal of TMS induced EEG artefacts.

Methods

Participants

- A sample of six participants (18-82) were randomly selected from a larger cohort study (by an independent clinician) where all participants had previously received occipital cortex TMS whilst recording EEG (128 channel). Stimulation intensity was set using the individual's phosphene threshold.
- Analyses was conducted with the analyst blind to the participant demographics to avoid bias.

Event Related Potentials

- Trials were split into epochs of 2048ms (-1024:+1024ms) and baseline corrected using the period of -210:-10ms.
- Poor trials were removed after ICA cleaning to reduce the influence of extraneous artefacts.

Independent Components Analysis

- EEG Signals were decomposed using FASTICA and optimised to prevent overlearning (e.g. Korhonen et al, 2010). Components were classified by an experienced EEG analyst. ICA was performed at two stages (see figure 1).

Component Removal

- Temporal envelope of the component ERP's was computed. Components were then ranked in order of their contribution to the envelope, within a given window.

#1: Pulse Removal (-40:+40ms)

- Sharp changes in potential and characteristic decay artefacts (see figure 2).

#2: Common Artefacts (-200:+500ms)

- Sources of muscular artefacts, blinks, and line noise (50Hz).

Reliability

- Global field power (Lehman & Skrandies, 1980) was estimated at each stage in the process (pre-cleaning; one round of ICA; 2 rounds of ICA; completed ERP).
- To measure the effect of component removal on the EEG signal we recorded the following at each stage: percentage of components removed; early artefact amplitude(0-20ms); the number of peaks in the GFP.

Analysis

- We performed non-parametric comparisons of the reliability data at each stage of the cleaning within and between repetitions of the protocol.

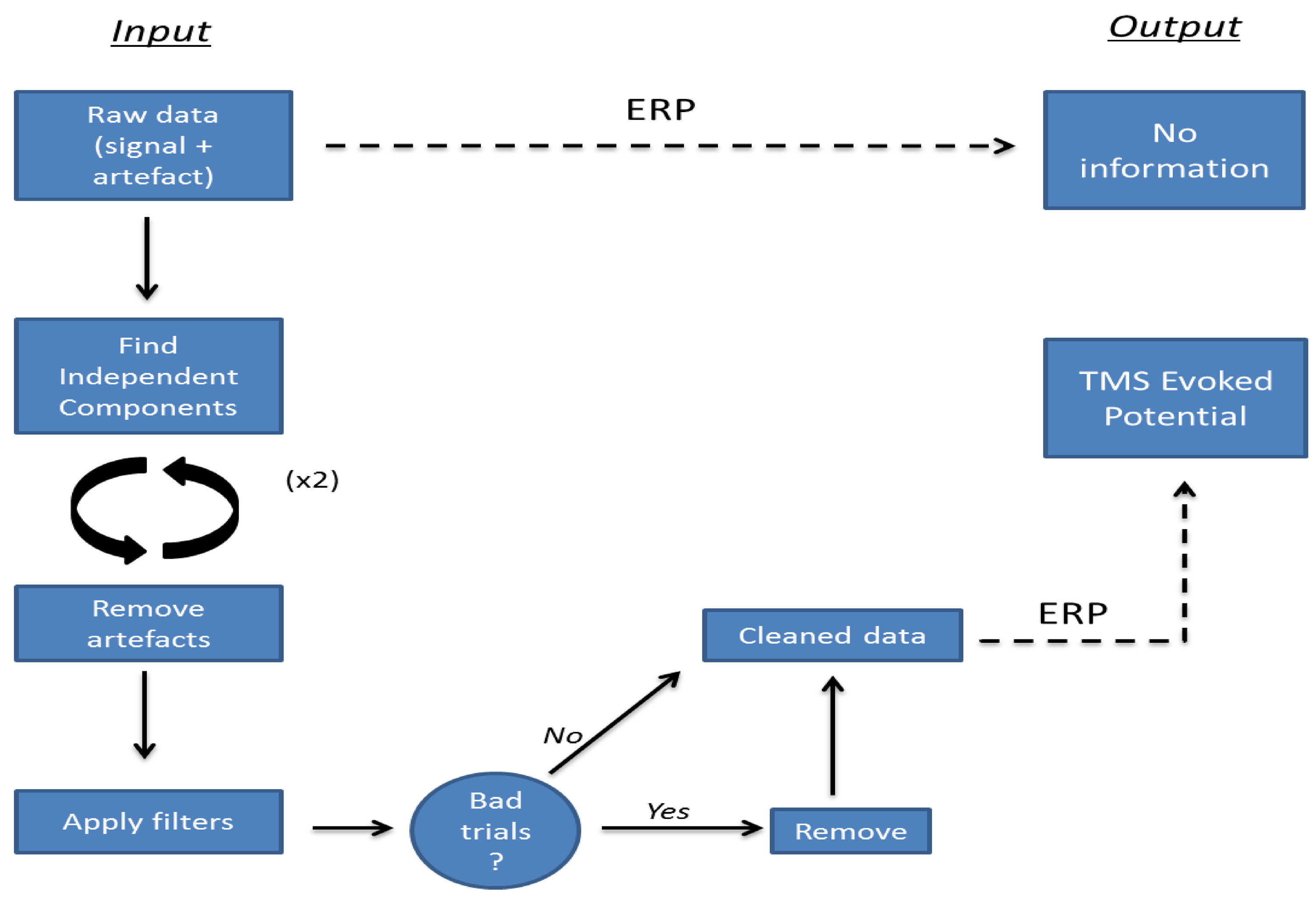

Figure 1: Schematic of methodology

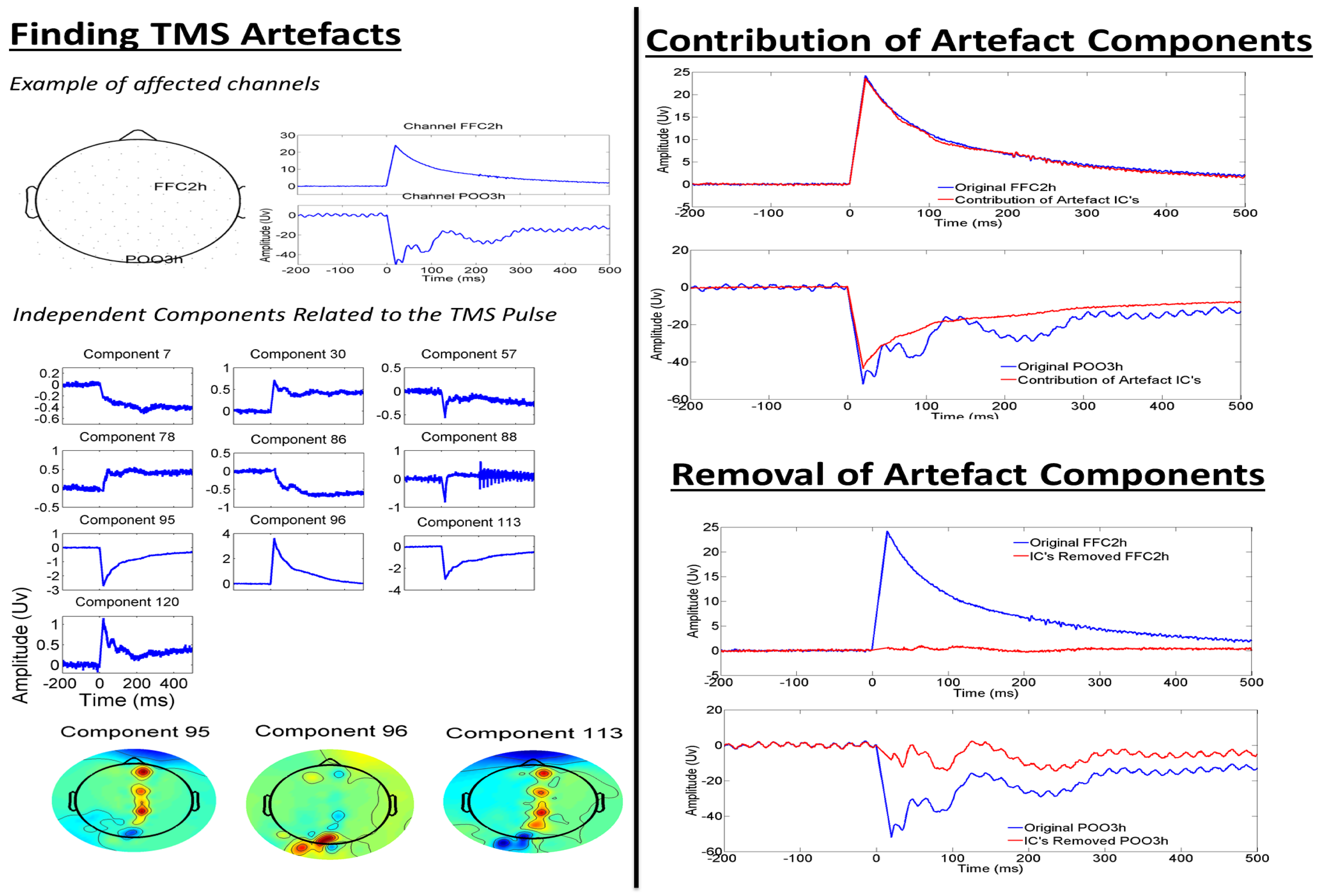

Figure 2: The process for determining the contribution of the components contributing the most to the temporal envelope. Contribution was analysed by first excluding components not thought to be artefact. Artefact components were then removed if they failed to show any signs of contributing a cortical EP.

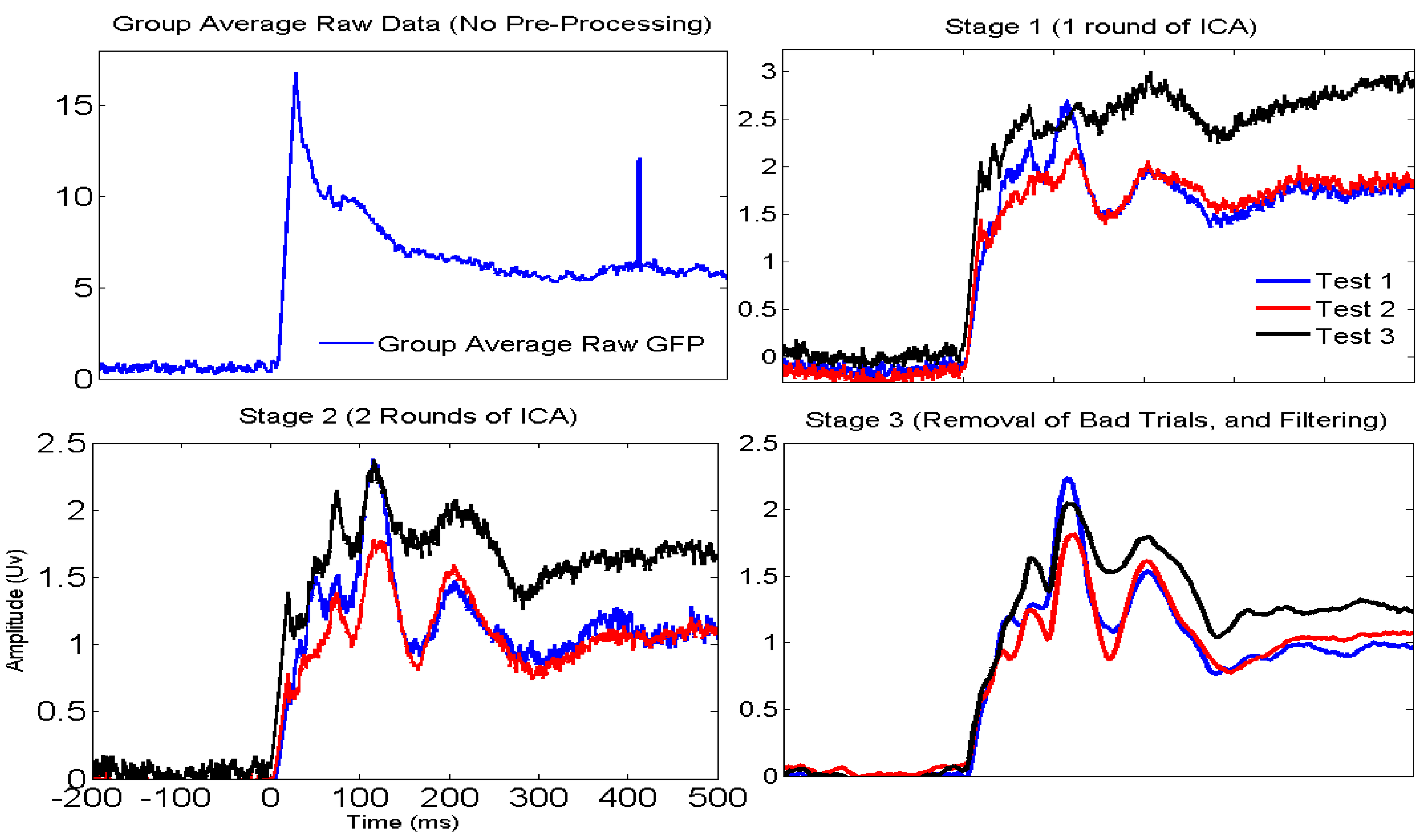

Figure 3: Comparison of artefact period amplitude, and GFP structure at each stage of the process, and the reliability of this approach in 3 separate tests.

Results and Conclusions

- Figure 3 demonstrates the inspection of the GFP at each stage of the process, and repeated on 3 separate occasions. Over time we see that the amplitude of the artefact period is significantly reduced (mean, 5.5 µv ; $\chi 2(11)= 58.432$, $p<0.05$), and that the peak structure of the GFP remains unchanged (mean, 3.68, sd, 0.76; $\chi 2(5)= 13.866$, $p=.240$).
- Additionally, this was achieved with no differences in the percentage of components removed (mean 12.4%; sd 3.2; $\chi^2(5)= 2.927$, $p=.711$).
- We have demonstrated that it is possible to reliably perform an effective removal of the mechanical and muscular artefacts induced by the TMS-evoked potential.
- This was performed without damaging the structure of the resulting ERP waveform. Despite the small sample size the outcome is such that the use of ICA to remove these artefacts can be standardised and confidently applied between subjects to elicit comparable outputs.
- We suggest that this methodology be considered as a baseline for the further refinement of approaches to the pre-processing of combined TMS-EEG data.

References

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